METHODS FOR THE QUALITATIVE EVALUATION OF A MATERIAL WITH AT LEAST ONE IDENTIFYING CHARACTERISTIC

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This patent application is the U.S. national phase, under 35 USC 371, of

PCT/EP2004/050378, filed March 26, 2004; published as WO 2004/086291 A2 on

October 7, 2004, and claiming priority to DE 103 14 071.9, filed March 28, 2003,

the disclosures of which are expressly incorporated herein by reference.

FIELD OF THE INVENTION

[002] The present invention is directed to methods for the qualitative evaluation

of a material having at least one identifying characteristic A color image is

recorded by an electronic image sensor of at least the identifying characteristic.

BACKGROUND OF THE INVENTION

[003] Camera systems are increasingly employed in the printing industry in

connection with various applications, such as, for example, in inspection systems,

in path monitoring systems or in registration measuring systems. These systems are typically arranged for use with a printing press or with a machine which processes material to be imprinted. Moreover, there is a requirement that these systems should perform their functions "in-line", integrated into the working process of the printing press or of the machine processing material to be imprinted. This "in-line" requirement presents a considerable challenge to the respective camera system because of the large amount of data provided by the camera system and because of the rapid process speed of the printing press or of the machine processing the material to be imprinted. It is difficult, for example, to obtain a dependable evaluation, preferably of each identifying characteristic, and even of identifying characteristics which are difficult to identify by spectral photometry, in spite of the high transport speed of the material, during the short time available for making an evaluation in the course of a quality control. Electronic image sensors are often used in such camera systems for recording images. In particular, these systems often use color cameras with an image sensor consisting of a CCDchip, whose light-sensitive pixels provide an output

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signal, usually, for example, in three separate signal channels, primarily for the

colors red, green and blue, that are corresponding to the color recorded in the

observed range.

[004] A problem that exists with known camera systems in connection with

testing colored material, and in particular with testing material imprinted in colors,

consists in that the image data provided by the color cameras often do no

correspond to the color perception of the human eye. Unprocessed image data

received from these color cameras are often insufficient with respect tocolor

balance, brightness, contrast and color tone reproduction with respect to the color

match corresponding to the human color perception. The main reason for this

problem, besides the insufficiencies of lenses and illumination devices, is the

spectral sensitivity distribution of the color cameras which are employed. If the

sensitivity distributions of the color cameras employed does not match the

sensitivity distribution of the human eye. The result is that, in the course of

subsequent further processing, for example when the image data is displayed on

a color monitor, the image data provided by the color cameras lead to a false

visual impression. During checking, a reasonable qualitative evaluation of the

imprinted material is hardly possible for this reason alone.

[005] As a result of previous production processes, it can occur that the position

of a detection characteristic to be evaluated during the checking process varies

within certain tolerance limits in a defined expected range. For example, the

position of a window thread, such as is used, for example, in connection with bills

or with stamps, in relation to the print image of the bills or stamps on a printed

sheet, can vary because of the properties of the production process for producing

the window thread. Such acceptable position deviations of certain identifying

characteristics can generate a malfunction report in inspection systems, since a

print pattern defined as a reference value is compared sequentially, print position

by print position, with the actual printed image. The result is that deviations in the

position of identifying characteristics are detected as errors, although they are, in

fact, not errors.

[006] For example, a method is known from DE 196 13 082 A2, wherein an

imprinted material, such as, for example, a print sheet imprinted with bills and

provided with a silver thread, hologram or kinegram, is illuminated by an

illuminating device in such a way that the light reflected by the imprinted material

enters a photoelectric sensor. The image taken by the photoelectric sensor can

thereafter be evaluated in an evaluating device, such as, for example, in a

standard computer provided with suitable evaluation software, and can be

checked for printing errors. However, in this case, it is a requirement, for

conducting the evaluation, that an identifying characteristic, whose position varies,

have a sufficiently high reflecting capability, if, for example, it is embodied as a

shiny silver thread. Accordingly, it is disadvantageous that, after having been

recorded by the use of the photoelectric sensor, that identifying characteristics,

whose image properties do not differ sufficiently strongly from the image

properties of the remaining print image, such as is the case with, for example,

colored window threads, cannot be detected by the evaluation device with

sufficient reliability.

[007] A method for the qualitative evaluation of a material with at least one

identifying characteristic is known from DE 101 32 589 A1. An image of the

material to be evaluated is recorded by an image sensor. The geometric contours and/or the relative arrangement of several identifying characteristics of this image are evaluated, with respect to each other, in an evaluation device.

[008] A method for signal evaluation of an electronic image sensor, in connection with detecting the patterns of image contents of a test body, is known from post-published DE 102 34 086 A1. A decision regarding the assignment of the test body to a defined class of test bodies is made.

[009] A measuring arrangement for identifying valuable objects by digital image analysis is known from DE 198 02 781 A. A narrow-band excitation light source, such as, for example, a tunable laser, illuminates a selected location area of the object with light within a narrow frequency range. Light, which is reflected by the object, or an emission that is induced in the object because of its being exposed to radiation, is, for example, detected by a photometrically calibrated CCD camera having a multitude of pixels, is digitized and is forwarded to a computer in the form of a data set characterizing each pixel and is stored in a memory. The photographically detected object can also be additionally surveyed, so that

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information regarding a geometric arrangement of various objects, their distance

from each other or the depth of their relief structure, can be added to the data set.

The data set which is prepared from this image detection can be made available,

for example via the internet, and can be used for a comparison of this data set

with a data set prepared for another object, in order to check the other object at

the different location for determining its agreement with the first object, i.e. the

original object, and therefore to check its genuineness.

[010] An arrangement for the classification of a pattern, in particular of a bill or a

coin, is known from CH 684 222 A5. A multi-stage classification system, which is

capable of learning, sequentially performs at least three tests on a pattern by

comparing characteristic vectors with vectorial desired values. A light source

illuminates the pattern and a sensor measures the radiation reflected by the

pattern at discrete points in time.

[011] Methods for pattern recognition customarily determine similarities such as,

for example, distance measurements on segmented objects, or their calculated

global threshold distributions. These methods are based on translation- invariant

initial spectra. However, situations often occur in real life, such as by object displacements underneath the recording system, for example, by the existence of different backgrounds during the recordings, or because of aliasing effects, so that in many cases a direct comparison of these initial spectra with stored reference values cannot be performed.

SUMMARY OF THE INVENTION

[012] It is the object of the present invention to provide methods for the qualitative evaluation of a material with at least one identifying characteristic, which methods can be employed in the printing industry.

[013] In accordance with the invention, this object is attained by recording a color image of the material having at least one identifying characteristic. A color image is recorded, using an electronic image sensor, of at least the identifying characteristic. At least one first electrical signal, which is correlated with the color image, is made either directly or indirectly by the image sensor. An evaluating device, which is connected with the image sensor, evaluates the electrical signal.

A second electrical signal is obtained from a reference image and is stored in a data memory. The first and second signals are compared.

[014] The advantages to be obtained by the present invention lie, in particular, in that a material, and in particular, an imprinted material with at least one identifying characteristic, can also be dependably qualitatively evaluated if the color image taken of the material, and in particular of the identifying characteristics, has optical properties which cannot be sufficiently identified byspectral photometric methods alone. The method of the present invention does not require that the material to be evaluated qualitatively have a distinctive reflection capability. It is thus possible to define practically any arbitrary, optically detectable property or condition of the material as its identifying characteristic, so that a clearly expanded application range of the method results. It is therefore possible to decide what the identifying characteristics should consist of as a function of the application. The test is solely dependent on there being an optically recognizable difference between the identifying characteristic and its surroundings. This difference is utilized for qualitatively evaluating the material, which evaluation can also include, for

example, the material's identification or a test of its genuineness.

[015] In particular, the proposed method leads to good results, if it is also assumed that the position of the identifying characteristic varies within an expected range which is determined by tolerance limits. Moreover, with respect to color hues, fullness and brightness, the colors picked up by the image sensor are arranged sufficiently accurately, in a color range which corresponds to the color perception of the human eye, so that the material is reproduced by a display device, such as, for example, by a color monitor, in the form of a color image in such true colors, as if the material were inspected directly by a human eye, so that a dependable qualitative evaluation of the material, and therefore also of its identifying characteristics, becomes possible by use of the color image.

[016] The so-called CIELAB color range, which has found wide application in printing technology, for example, is suitable for use as the color range. An important characteristic quantity of color deviation in the CIELAB color range is provided by the color distance ΔE between the reference variables and the actual values of the parameters L, a and b, which characterize the CIELAB color range.

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The parameter L identifies the brightness, a identifies the red-green value and b identifies the yellow-blue value. These parameters are also called CIE values.

Further characteristic quantities are the color hue difference Δ H and the fullness difference Δ C, wherein the color hue difference Δ H, in particular, is important as a characteristic quantity in multi-color printing. This is because an off color is subjectively perceived to be more disturbing than a fullness difference Δ C indicating a brightness difference. Thus, for example, a color distance Δ E of a value 1 means a non- visible color difference, a value of 2 means a small difference, a value of 3 means a recognizable difference, a value of 4 means a clear difference and, starting at a value of 5, a large difference. The value range of the CIE values a and b respectively extends from -100 for green or blue to +100 for red or yellow. The value range for brightness L extends from 0 (black, total absorption) to 100 (white, total reflection). The value triplet L = 50, a = 0, b = 0 identifies a neutral medium gray.

[017] Three types of cones (S, M, L) exist in the human eye, which cones absorb light entering in different spectral ranges. The maximum absorption of the S-type

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cones lies in the blue range, namely at 420 nm. The M-type cones maximally

absorb light in the green spectral range, namely at 534 nm. The maximum of the

L-type cones lies at 564 nm in the yellow/red spectral range. Perception by the

use of three cone types is called tri- chromatic perception. Individual color

perceptions are triggered by stimulation of different strength of the individual cone

types. An identical stimulation of all cone types leads to the perception of the

color white.

[018] Color perception phenomena, such as color antagonism and color

constancy, for example, cannot be explained by the tri-chromatic perception

model. Color antagonism means that certain colors can never be seen in

transition, so that no color transition between these colors is possible. Colors

demonstrating color antagonism are called compensation colors or

complementary colors. To be cited among these are the color pairs red/green and

blue/yellow, as well as black/white. In color constancy the different spectral

distribution of the light which, for example, is a function of the weather or of

daylight conditions, is compensated.

[019] Hering developed the compensation color theory in 1920 to explain these color perception phenomena in a way different from the classic tri-chromatic color model. The compensation color model assumes that the cones are arranged in receptive fields, namely in blue/yellow fields and red/green fields. In this case, receptive fields are understood to be neurons, as well as the manner in which the stimulation of the cones is further processed by the neurons. Two types of receptive fields are substantially responsible for color perception. The first receptive field obtains its input from the L- and M-cones, the second receptive field receives its input from the S-cones, together with differently weighted stimulations of the L- and M-cones. It is assumed that a subtractive color mixture is performed on the level of the neurons or receptive fields for stimulating the cones.

[020] The RGB model is the tri-chromatic model for describing additive color images which is most used in technology. In the RGB model, the color range is described by the three basic colors red, green and blue. With this model, it is particularly disadvantageous that the description performed by use of the RGB

model does not correspond with the perception of the human eye, since the behavior of the human perception in particular, i.e. the perception through the senses, is not being taken into consideration.

[021] As a rule, electronic image sensors, and in particular CCD chips for color cameras, have a multitude of, such as, for example, a million or more, light-sensitive pixels, which are, for example, arranged in a matrix-shape, each of which pixel, as a rule, provides a first electrical signal corresponding to the colored light recorded in the observed area and correlated with the color image, which first electrical signal is split up, for example, in three signal channels which three signal channels are separated from each other. At the time of the observation, each signal channel makes available a portion of the first electrical signal mainly corresponding to one of the basic colors red, green and blue. Such a signal is called an RGB signal. Usefully, a spectral sensitivity of each signal channel ®, G, B)is matched to the spectral sensitivity of the human eye, for example R = red to 564 nm, G = green to 534 nm and B = blue to 420 nm. Also, the first electrical signal, in its entirety, is matched with respect to hue, fullness and brightness, to

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the color perception of the human eye. Accordingly, a color image recorded by

the use of such a color camera is composed of a multitude of image points.

[022] The method in accordance with the present invention is now distinguished

in that a second electrical signal is obtained from at least one reference image

and is stored in a data memory. The second electrical signal constitutes at least a

reference variable for the first electrical signal. By a comparison of the first signal

with the second signal, at least the color image of the identifying characteristic is

checked for a color deviation from the reference image, and/or the identifying

characteristic is checked for its affiliation with a defined class of identifying

characteristics, and/or for its affiliation with a defined geometric contour and/or for

a relative arrangement with at least one further identifying characteristic of the

material, each by a comparison of the first signal with the second signal for having

reached the reference variable or an agreement therewith. To increase the test

dependability, the material and/or its identifying characteristic is preferably

simultaneously always checked with regard to at least two of the above mentioned

criteria. To this end, at least two of the tests of the color image, and, in particular,

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the test of the identifying characteristic for a color deviation from a reference

image, and the test of the identifying characteristic for its affiliation with a defined

class of identifying characteristics or with a defined geometric contour, or a

relative arrangement with further identifying characteristics of the material

preferably take place, at the same time, in parallel test procedures which run

independently of each other. By the use of the present method, an evaluation of

imprinted material, in a running printing process of a printing press, or in a running

work process of a machine, which further processes the imprinted material, is

possible for accomplishing the quality control of this material. This is because of

the resultant test dependability and because of the testing speed with which the

performance of the present method takes place. This material constitutes, in

particular, high-quality printed products which, for example for security reasons,

require very careful testing, and on which great demands are made, regarding, for

example, the stability of their condition with regard to print technology, i.e. bills and

stamps, in particular.

[023] Testing the color image, for color deviation of the color image from the

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reference image, preferably takes place in that the portion of the first signal from the color image made available in the first signal channel is linked by a first calculation prescription with the portion made available in the second signal channel. An output signal from a first compensation color channel is generated so that the portion of the first signal from the color image made available in the third channel is linked with the portions in the first and the second signal channel by a second calculation prescription, by the use of which an output signal from a second compensation color channel is generated. The output signals of the compensation color channels are classified by being compared with reference variables.

[024] Testing the identifying characteristic, regarding its affiliation with a defined class of identifying characteristics, is preferably performed in that the first electrical signal made available by the image sensor is converted by the use of at least one calculation prescription into a translation-invariable signal with at least one characteristic value. The identifying characteristic is weighted with at least one fuzzy association function. A higher-order fuzzy association function is generated

by linking all association functions by use of a calculation prescription consisting of at least one rule. A sympathetic value is determined from the higher-order fuzzy association function. The sympathetic value is compared with a threshold value. As a function of the result of this comparison, a decision is made regarding the affiliation of the identifying characteristic with a defined class of identifying characteristics.

[025] Testing of the identifying characteristic, regarding a defined geometric contour, and/or a relative arrangement with at least one further identifying characteristic of the material, preferably takes place in that at least one background reference variable and at least one mask reference variable are stored in the memory. The background reference variable represents at least one property of the material to be evaluated in at least one portion of an area of the vicinity surrounding the identifying characteristic. The mask reference variable represents the geometric contour of the identifying characteristic or the relative arrangement of several identifying characteristics among each other. In the course of testing the material, a difference value, at least of the expected range, is

formed from the first electrical signal made available by the image sensor and

from the background reference variable. The actual position of the identifying

characteristic is derived from a comparison of the difference value with the mask

reference variable. For the qualitative evaluation of the material the portion of the

material to be evaluated, which results from the actual position of the identifying

material, is blanked out.

[026] The adaptation of the first electrical signal to the color perception of

ahuman's eye takes place in that the RGB signal made available by the image

sensor at every observation time is considered to be a vectorial output signal. The

coefficients of the RGB signal vector are multiplied with a correction matrix which

is quadratic in particular, so that all portions of the first electrical signal

represented in a signal channel are approximated to the color perception of the

human eye. By multiplying the RGB signal vector by a correction matrix, a

relatively accurate interrelation of all print colors in a basically arbitrary color range

is achieved. Moreover, a matching of the RGB signal vector, by use of the

multiplication with the correction matrix, can be easily realized by use of data

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technology, so that an implementation into an actual system is possible even with

large amounts of RGB signals which are made simultaneously available by a

multitude of pixels of the image sensor.

[027] The coefficients of the correction matrix are, of course, of decisive

importance for the quality of the proposed correction of the RGB signals since,

depending on the selection of these coefficients, the RGB signal vectors are

transformed in different ways. For example, the coefficients of the correction

matrix can consist of empirical values. They are stored in a data memory.

[028] To match the coefficients of the correction matrix variably to different side

constraints, such as, for example, regarding the color camera used, to the

illumination conditions, or to the lenses used, an iterative approximation algorithm

is proposed. A reference color chart, such as, for example, an IT8 chart with 288

color fields, is preset for performing this approximation algorithm. The different

reference colors are represented in the color fields. Moreover, the assignment of

the different reference colors to a suitable color range, for example, to the CIELAB

color range, is known. From these preset CIELAB values for the various

reference colors of the reference color chart, it is possible, by the use of known transformations, to calculate corresponding reference variables for the three signal channels. Thus, a reference color chart is preset as the input value for the approximation algorithm, and for each reference color as a vector with a reference variable for each color channel as a desired result of the conversion. In the course of performing the approximation algorithm for the determination of the coefficients of the correction matrix, the reference color chart is recorded by use means of the image sensor of the color camera, and an RGB signal vector is determined for each color field. The difference between these RGB signal vectors of the color camera and the vector with the preset reference variables corresponds to the difference between the color perception of the human eye and the sensitivity distribution of the color camera.

[029] In order not to have to calibrate the illumination source to a standard light source, when using respective camera systems, it is possible to perform a further correction step. In this further correction step, the coefficients of the RGB signal vectors are converted in such a way that the result corresponds to those RGB

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signal vectors which would be obtained when illuminating the observation area by the use of standard light. The color correction values for use in matching the RGB signal vectors to different illumination sources and changes can be advantageously calculated in the following way.

[030] At present, the standard light D50 is still being used in printing technology. By specifying the illuminant D50, it is possible to adapt Rec. 709 to D50 standard light by a conversion so that the non-linear RGB signal vectors behave as if the object to be tested were illuminated by D50 illumination. It is possible, by use of the method of the present invention, to match the RGB signal vectors iteratively to the CIELAB color range without an actual standard illumination being necessary. This method has the advantage that, in case of an expected change of the specified standard light, a match can immediately be provided.

[031] The starting point of the iteration is a correction matrix whose coefficients have been preset as the initial values. These initial values can either be selected purely accidentally, or corresponding to defined empirical values. In the first iteration step, this correction matrix is now multiplied by all of the RGB signal

vectors made available by the image sensor, and the corrected RGB vectors thus obtained are temporarily stored in a data memory. Subsequently, the coefficients of the correction matrix are slightly changed, and the multiplication is again performed. The change of the coefficients of the correction matrix is respectively only performed if the corrected RGB signal vectors approximate the vectors with the preset reference variables.

[032] The approximation of the corrected RGB signal vectors to the vectors with the preset reference variables is weighted for each iteration step in order to be able to determine by this weighting, whether the change of the coefficients of the correction matrix performed made in this iteration step is to be accepted or discarded. An advantageous weighting method provides, that for each color field of the reference color chart, the difference value between the corrected RGB signal vector and the vector with the preset reference values for this color field is determined and the sum of all these difference values is added. The change of the correction coefficients of the correction matrix in the actual iteration step is only accepted if the sum of all difference values in this actual iteration step has

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become smaller, in comparison to the sum of all difference values in the previous

iteration step. If the sum of all difference values has become greater, because of

the change of the coefficients of the correction matrix in the previous iteration

step, the change of the coefficients is discarded. By use of this summary

consideration of the difference values of all reference colors, it is easily possible

that the difference between individual reference colors is increased during an

iteration step. However, as a whole, the minimization of the difference values is

dependably assured over all signal channels.

[033] A further problem in connection with the use of camera systems is the

correct setting of the color balance, i.e. the correct weighting of the various signal

channels with respect to each other. In order to adjust the color balance of the

individual signal channels relative to each other, the coefficients of each RGB

signal vector can be multiplied with a correction factor which is a function of the

signal channel. At the same time, a correction factor is added to each RGB signal

vector. This correction of the three signal channels of each RGB signal vector

corresponds to a linear displacement of the individual coefficients of the RGB

signal vectors.

[034] A particularly good color balance is achieved if the correction vector, and the correction vectors which are a function of the signal channels, are selected in such a way that the corrected RGB signal vectors obtained by the application of the correction by use of the correction vector and of the correction factors for the two fields with the reference gray values black and white substantially correspond exactly to the vectors with the preset reference variables of these two color fields. In other words, this means that the linear displacement of the RGB signal vectors is selected to be such that corrected results are obtained for the two reference gray values black and white which correspond to the color perception of the human eye. Preferably, this linear displacement is applied to all of the RGB signal vectors, so that brightness and contrast are automatically also corrected over the entire color spectrum.

[035] When using color cameras, color distortions and a reduction of intensity, particularly at the edges of the camera images, can occur. These distortions are generated by the optical devices used, such as, for example, by the lenses used.

A so- called shading correction can be employed to correct this intensity reduction. To this end, correcting factors, as a function of the signal channel, are specified for each pixel. By multiplying these pixel-dependent correction factors with the coefficients of the RGB signal vectors, it is possible to compensate for the pixel-specific color distortions or for a reduction of the intensity because of the structural type in the various areas of the image sensor.

[036] For example, it is possible to detect these pixel- specific, signal channel-dependent correction factors experimentally in a simple manner. The observed area of the color camera is lined with a homogeneous material, and in particular with a homogeneous white material, and an RGB signal vector is determined for each pixel by use of the camera. The RGB signal vector having the highest value coefficients, and which therefore represents the brightest location in the observed area, is filtered out of these RGB signal vectors. However, since the observed area has been lined with a homogeneous colored material, all of the pixels should provide substantially identical RGB signal vectors. Therefore, the respective differences are based on color distortions or on a reduction in intensity as a result

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of the structural type. To compensate for this, correction factors are now selected

for each signal channel of each individual pixel, which correction factors see to it

that, in the course of recording the homogeneous colored material, all of the RGB

signal vectors correspond to the RGB signal vector at the brightest location in the

observed area.

[037] Color distortions depend, in particular, greatly on the illumination conditions

in the observed area. To prevent error sources based on a change of the

illumination conditions, the illumination used during the experimental

determination of the pixel-specific, signal channel-dependent correction factors of

the illumination should therefore correspond to the illumination used during the

subsequent employment of the camera system.

[038] In many cases of the application of the method for matching the first

electrical signal to the color perception of the human eye, the corrected RGB

signal vectors, obtained by the correction of the RGB signal vectors originally

made available by the color camera, are employed for controlling the separate

signal channels of a color monitor. Here, the representation of the colors on the

color monitor also creates the problem that the representational characteristics of most color monitors do not correspond to the color perception of the human eye. This is based, in particular, on the fact that the brightness behavior of the color monitor is, as a rule, not linear, so that the intensity of the light produced at the color monitor is a non-linear function of the electrical input signals arriving at the color monitor, in this case of the RGB signal vectors. This means that, in the case where the RGB signal vectors, which had been corrected to match the color perception of the human eye, are merely transmitted to the color monitor and are displayed there, without taking the non-linearity of the monitor's brightness behavior into consideration, undesired distortions in the color image can occur on the color monitor. In that case, a dependable qualitative evaluation of a material represented on the color monitor, in particular of a material with an identifying characteristic, is then objectively not possible.

[039] To prevent such color distortions in connection with theirrepresentation on a color monitor, the coefficients of the corrected RGB signal vector, which had been used as a basis, can each be raised to a higher power by a factor γ. By this

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non-linear conversion of the coefficient of the corrected RGB signal vector, it is

possible to compensate for the non-linearity of the brightness behavior of most

color monitors. It is necessary, for most color monitors, to select a value in the

range between 0.3 and 0.5, and in particular of approximately 0.45, for the factor

γ.

[040] In the method of testing the color image for a color deviation from the

reference image, the processing of the stimulations, in connection with human

color perception, is simulated. To reproduce the three cone types of the human

eye, with their differing spectral sensitivity, a signal vector is made available by

each pixel for the color image recorded by the color sensor,as already mentioned,

whose coefficients preferably represent three signal channels that are separated

from each other. Each one of the three signal channels has a characteristic

spectral sensitivity. The two receptive fields representing the second stage of

color processing in human vision, are simulated by an appropriate linkage of the

three separate signal channels. The red/green field of human color perception

represents the first compensation color channel in the technical model. The

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output signal of the first compensation color channel is generated by the linkage of the portion of the signal vector in the first signal channel with the portion of the signal vector in the second signal channel. Linkage takes place by a calculation prescription consisting of at least one arithmetic rule. The blue/yellow field is created in the technical model by the linkage of the portion of signal vector in the third signal channel with a combination of the portions of the signal vectors from the first and second signal channel. In the technical model, the blue/yellow field corresponds to the second compensation color channel. The output signal of the second compensation color channel is generated by the above-described linkage. Linkage takes place by the use of a second calculation prescription consisting of at least one arithmetic rule. To evaluate the signal vector of the tested pixel, a classification of the output signals of the two compensation color channels takes place in the next step. By this process, it is determined whether the signal vector of the tested pixel, and therefore in the end also of the color image, corresponds to a defined class, by which determination a good/bad classification can be made.

[041] For the principle of the method of the present invention, it is of negligible

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importance in which spectral range the signal channels of the method operate, as long as they are signal channels of different spectral sensitivity. It is advantageous if the signal channels correspond to the three basic colors of the RGB model, namely red, green and blue, because with this, use is made of a widely distributed color model. The spectral sensitivity of each signal channel is advantageously matched to the spectral sensitivity of the cone types in the retina of the human eye.

[042] It is of secondary importance, in accordance with the principle of the present invention, in which way the two output signals of the compensation color channels are generated. One option lies in that an arithmetic rule of the first calculation prescription provides a weighted difference formation of the portion of the signal vector in the second signal channel from the portion of the signal in the first signal channel, and/or that an arithmetic rule of the second calculation prescription provides a weighted difference formation of the weighted sum of the parts of the first and second signal channel from the portion of the third signal channel.

[043] Preferably, at least one signal, in at least one compensation color channel, is subjected to a transformation prescription after and/or prior to the linkage, and in particular is subjected to a non-linear transformation prescription. A transformation has the particular advantage that the digital character of electronically generated color images can be taken into consideration. By use of the transformation prescription, it is also possible to transform a signal from the color range into a range, in which the stimulation of the cones can be described. Preferably, the signals in both compensation color channels are subjected to a transformation.

[044] Since the receptive fields in human vision are characterized by a low pass behavior, it is sensible to filter at least one signal in at least one compensation color channel by the use of a low pass filter. Preferably, the output signal of every compensation color channel is filtered by a low pass filter.

[045] Preferably, the method in accordance with the present invention has a learning mode and a working mode. In particular, an evaluation device, which is processing the signals from the image sensors, can be switched between these

two operating modes, i.e. between the learning mode and the working mode.

During the learning mode, at least one reference image, such as, for example, the

recording of at least a single printed sheet, is checked pixel by pixel, and the

output signals from the two compensation color channels generated by the

reference image are stored in a data memory as a second electrical signal

constituting a reference variable. In actuality, this means that a signal vector of

the reference image is made available, for example, in three signal channels, that

the portions of the signal vector made available in each signal channel are

matched with respect to perception, and that these portions are thereafter linked

with each other corresponding to the compensation color model. Then the output

signals from each compensation color channel are stored pixel by pixel in the data

memory. In the subsequent working mode, the output signals of the respective

pixel, created by a color image to be tested, are compared with the corresponding

values stored in the data memory in the form of reference variables, and a

classification decision is then made.

[046] In order to take permissible color fluctuations of the color image, as well as

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fluctuations of the conditions during the taking of the image into consideration, it is

practical for the values stored in the data memory to be formed by several

reference data sets, so that a permissible tolerance window is fixed in the data

memory for each value, within which permissible tolerance window an output

signal value of a compensation color channel, generated during the image testing,

is permitted to fluctuate. In this case, the reference variable of the output signal of

a compensation color channel can be determined, for example, by arithmetic

average value formation from the individual values, wherein the individual values

result from the reference data sets. For example, the tolerance window can be

determined by the minimum and maximum values of, or by the standard deviation

from, the output signals generated by the tested reference images of the

compensation color channel of each pixel.

[047] The method for checking the identifying characteristic, regarding its

affiliation with a defined class of identifying characteristics, preferably proceeds

through the following substantial method steps: characteristics formation,

fuzzyfication, interference, de-fuzzyfication and decision regarding a class

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affiliation.

[048] During the characteristics formation, the first electrical signal made

available by the image sensor is converted, by the use of at least one calculation

prescription, into a translation-invariant signal within a range of characteristics.

The aim of the characteristics formation is the determination of those values by

the use of which typical signal properties of the color image are characterized.

The typical signal properties of the color image are represented by so-called

characteristics. In this case, the characteristics can be represented by values

within the characteristic range, or by linguistic variables. A signal is created by the

conversion of the first electrical signal in the characteristic range, which signal

consists of one characteristic value or of several characteristic values.

[049] The affiliation of a characteristic value with a characteristic is described by

at least one fuzzy affiliation function. This is a soft, or is a fuzzy association

wherein, as a function of the value of the characteristic value, the affiliation of the

characteristic value with the characteristic exists within a standard interval

between 0 and 1. The concept of affiliation leads to a characteristic value no

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longer being either wholly affiliated, or not at all affiliated with a characteristic.

Instead, it can take on a fuzzy affiliation which lies between the Boolean logical

values 1 and 0. The above- described step is called fuzzyfication. Thus, during

fuzzyfication, a conversion of a hard characteristic value into one or into several

fuzzy affiliations substantially takes place.

[050] In the course of interference, a higher level affiliation function is generated

by a calculation prescription consisting at least of one rule, wherein all affiliation

functions are linked together. As a result, a higher order affiliation function is

obtained for each window.

[051] In the course of de-fuzzyfication, a numerical value is determined from the

higher order affiliation function formed from the interference, which numerical

value is also called a sympathetic value. During the decision regarding the class

affiliation, a comparison of the sympathetic value with a previously fixed threshold

value takes place, by which comparison, the affiliation of the window to a specified

class is decided. In this case, the threshold value forms a further reference

variable which is contained in the second electrical signal.

[052] It is of secondary importance, for the basic progression of the method in accordance with the present invention, of which type the characteristic values in the characteristic range are. For example, in the case of time signals, it is possible to determine their mean value or their variation as the characteristic values. If the requirement is made of the method for checking the identifying characteristic, for its affiliation to a defined class of identifying characteristics, that it is to process the color images free of errors, regardless of the respectively prevailing signal intensity, and if furthermore small, but permissible fluctuations in the color image are not to result in interferences, it is sensible to perform the conversion of the first electrical signal from the two-dimensional local range by the use of a two-dimensional spectral transformation. Examples of a suitable spectral transformation are respectively two-dimensional Fourier, Walsh, Hadamard or circular transformations. Translation-invariable characteristic values are obtained by the use of the two- dimensional spectral transformation. The value of the spectral coefficients, obtained by use of a spectral transformation, is preferably used as characteristic value.

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[053] The affiliation functions are preferably unimodal potential functions. The

higher order affiliation function is preferably a multi-modal potential function.

[054] It is advantageous to parametrize at least one affiliation function. If the

affiliation function has positive and negative slopes, it is advantageous if the

parameters of the positive and negative slopes can be separately determined. A

better matching of the parameters with the data sets to be examined is assured

bythis paramiterization.

[055] In accordance with a particularly preferred embodiment of the present

invention, the method is again divided into two different modes of operation,

namely into a learning mode and into a working mode. If the affiliation functions

are parametrized, it is possible, in the learning mode, to determine the parameters

of the affiliation function from measured data sets. In the learning mode, the

parameters of the affiliation functions are matched with so-called reference

images, so that in the learning mode, an affiliation of the characteristic values

resulting from the reference images with the corresponding characteristics is

derived by the use of the affiliation function and its parameters. In the subsequent

working mode, the characteristic values resulting from the subsequently measured

data sets are weighted with the affiliation functions whose parameters had been

determined in the learning mode, by the use of which, an affiliation of the

characteristic values of the now measured data sets with the corresponding

characteristics is established. Thus, the parameters of the affiliation functions are

determined by the use of measured reference data sets because of the division of

the method into a learning mode and a working mode. The data sets to be tested

are weighted in the working mode by the affiliation functions which were

determined in the learning mode and are evaluated.

[056] Furthermore, a rule by which the affiliation functions are linked with each

other preferably is a conjunctive rule within the meaning of an IF..THEN linkage.

[057] The generation of the higher order fuzzy affiliation functions is preferably

divided into the following partial steps: premise evaluation, activation and

aggregation. In the premise evaluation, an affiliation value is determined for each

IF portion of a rule, and during activation, an affiliation function is determined for

each If...THEN rule. Thereafter, during aggregation, the higher order affiliation

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function is generated by overlaying all of the affiliation functions created during activation.

[058] It is advantageous to perform the sympathetic value determination in accordance with a focus and/or a maximum method.

[059] Checking the identifying characteristic for a defined geometric contour and/or for a relative arrangement, with respect to at least one further identifying characteristic of the material, is based on the basic idea of additionally letting known information regarding this identifying characteristic enter into the evaluation in the course of evaluating a positionally variable identifying characteristic, for which the optical properties, for example the reflection capability, does not suffice for a sufficiently dependable identification. A premise in this case is that the positionally variable identifying characteristic, such as, for example, a colored window thread, differs in its optical properties, for example in its gray value, at least in partial areas, sufficiently from the remaining material to be inspected, such as, for example, the print image surrounding the identifying characteristic, so that there is at least no complete correspondence between the

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identifying characteristic and the print image. Thus, for determining the position of

the positionally variable identifying characteristic, additional information regarding

the contour, which is known per se, of the identifying characteristic or the relative

arrangement of several identifying characteristics contained in the print image are

evaluated. This additional information is then stored in a mask reference which is

stored in the data memory in regard to every material to be evaluated, which

represents the geometric data in a suitable form.

[060] Furthermore, a background reference variable has been stored as a

reference in the data memory, which background reference variable represents

the optical properties of the print image in at least a part of an area surrounding

the identifying characteristic. The optical properties of the background reference

variable must differ, at least slightly, from the optical properties of the identifying

characteristic to be detected. In the course of testing the material, a differential

value, which represents a differential image at least of the expected area, is then

formed from the actual first electrical signal made available by the image sensor

and the background reference variable.

[061] Substantially all of the characteristics of the print image, which correspond

in their optical properties to the background reference variable, are blanked out of

the differential image by the use of the difference formation. Only positionally

variable areas of the identifying characteristic and also of other elements, such as

printing errors or deviations of the edges, are represented in the differential image

because of their deviation from the background reference value, wherein the

areas of the positionally variable identifying characteristic have particularly high

amplitudes.

[062] As soon as the differential values are available, these differential values are

compared with the mask reference variables of the mask reference, and a

conclusion regarding the actual position of the identifying characteristic is drawn

from the result of the comparison. This method step is based on the reflection

that the differential image is substantially determined by the representation of the

positionally variable identifying characteristic, so that a conclusion regarding the

actual position of the positionally variable identifying characteristic can be drawn

from the considerable overlapping of the mask reference and the differential

image. If no sufficient overlap between mask reference variables and differential

values can be determined, because of other error effects, this is harmless, since

this merely leads to an error indication in the course of the print image check, for

example, and to the removal of the respective printed sheet.

[063] Preferably, the areas of the print image, resulting from the actual position of

the identifying characteristic, are blanked out during the subsequent qualitative

evaluation of the material, so that interferences with the checking of the print

image, because of the positionally variable arrangement of the identifying

characteristic, are excluded.

[064] The detection of the positionally variable identifying characteristic can be

improved during the performance of this method in that a threshold for binary

formation is stored in the data memory. After the differential image has been

formed from the first electrical signal and the background reference variable, all

image data, whose values lie below the threshold for binary formation, can be

filtered out of the differential image. This means that only those image points

remain in the differential image which differ with considerable significance from

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the remaining print image, so that the mostly other deviations, for example printing errors or edge deviations, can be blanked out of the differential image.

[065] The procedure, in the course of determining the position of the positionally variable identifying characteristic in the actual print image, can be such that the mask reference is shifted until a maximum overlap between the mask reference and the differential image results. Various mathematical evaluation methods can be employed for this, for evaluating the overlap between the mask reference and the differential image and for finding the appropriate overlap maximum. It is, of course, possible to provide the evaluation of the overlap by a visual check performed by sufficiently trained checking personnel which, however, because of the high costs of personnel and the low processing speed, is not sufficiently economical in most cases. Therefore, the calculation of the overlap between the differential image and the mask reference should take place by using suitable mathematical operations by the use of methods of electronic data processing, if possible.

[066] A possibility for evaluating the overlap between the mask reference and the

differential image consists in the calculation of foci in accordance with the optical

distribution of the image points in the differential image, and in comparing these

foci with the focus of the mask reference. Maximum overlap results when the sum

of the focus differences between the mask reference and the differential image is

minimized.

[067] A prerequisite for performing this method for testing the identifying

characteristic for a defined geometric contour and/or for testing a relative

arrangement, with respect to at least one further identifying characteristic of the

material, is the storage of a suitable background reference variable in the data

memory. In principle, the background reference variable can be simply preset as

a method parameter, such as, for example, a parameter based on one, or on

several empirical values. However, it is advantageous if the background

reference variable is specifically fixed in a learning mode as a function of the

respective print image of the material to be tested. Two alternatives of this will be

discussed in what follows.

[068] In accordance with a first alternative for determining the background

reference variable, reference material, which does not contain the positionally variable identifying characteristic, is used in the learning mode. For example, printed sheets imprinted with bills or stamps can be used for this, which printed sheets do not have the window thread. By evaluating this reference material without the identifying characteristic it is possible to derive the background reference variable.

[069] If reference material, without an identifying characteristic, is not available, the learning mode can also be performed using reference material containing the positionally variable identifying characteristic. If, in the course of evaluating the print image of the reference material, the positionally variable identifying characteristics appear bright, in comparison with the surrounding area, a threshold value, corresponding to the values of the darkest image points of the identifying characteristic, is selected as the background reference variable. In the course ofsubsequent testing of the material, it is then assumed, based on the threshold value, that, at least in the expected area, all image points which are darker than the background reference variable are not a part of the positionally variable

identifying characteristic. But, if in comparison with the surrounding area, the identifying characteristic appears dark, a threshold value is selected as the background reference variable whose value corresponds to the brightest image points of the identifying characteristic.

[070] To the extent that it is required on the basis of the optical properties of the print image, it is, of course, possible to define different background reference variables for different areas of the material, so that the positionally variable identifying characteristic is pictured with sufficient significance in the differential image.

BRIEF DESCRIPTION OF THE DRAWINGS

[071] Preferred embodiments of the present invention are represented in the drawings and will be described in greater detail in what follows.

[072] Shown are in:

Fig. 1, a block diagram with functional units which are relevant to the method in accordance with the present invention, in

Fig. 2, method steps in the course of performing the method for testing the

color image for a color deviation from a reference image in accordance with the

present invention, in

Fig. 3, a schematic representation of the method for testing for color

deviations in the recorded color image with a compensation color model, in

Fig. 4, a flow chart of the learning and working mode, as well as of the

classification, in

Fig. 5, a flow diagram of the method for testing the identifying characteristic

for its affiliation with a defined class of identifying characteristics, in

Fig. 6, a top plan view of a schematically represented differential image, in

Fig. 7, a differential image in accordance with Fig. 6 following the

performance of a binary formation, in

Fig. 8, a mask reference for determining the position of the positionally

variable identifying characteristic in the differential image in accordance with Fig.

7, in

Fig. 9, the overlap between the differential image in accordance with Fig. 7

and the mask reference in accordance with Fig. 8, in

Fig. 10, a second mask reference in a schematically represented side

elevation view, and in

Fig. 11, a second differential image in a schematically represented side

elevation view.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[073] A block diagram with the functional units relevant for the performance of a

method for the qualitative evaluation of an imprinted material 19 with at least one

identifying characteristic, in accordance with the present invention, is shown in

Fig. 1. A color camera 01, which, for example, has been attached fixed in place,

either in, or at a printing press, is positioned so that with its image sensor 02 it

can record color images of a material 19 to be evaluated. The material 19 is

moved past the color camera 01, preferably in the course of a running print

process, which color camera 01 is connected to an evaluating device 03. The

image data recorded by the color camera 01 and evaluated in the evaluating

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device 03 can be represented, if required, on a color monitor 04. The color

monitor 04 can be arranged in or at a control console, which is part of the printing

press. The testing methods which, in accordance with the present invention, are

used for the qualitative evaluation of the imprinted material 19, are represented in

connection with the evaluating device 03 in, for example, three parallel signal

paths. The testing processes in the respective signals paths preferably take place

in the same evaluating device independently of each other. The tests preferably

occur at least approximately at the same time. Typically, the test processes at

least start at the same time. The test process can start after the evaluating

device 03, which operates in at least two modes of operation, has changed from

its learning mode 48 into its working mode 49, as depicted in Fig. 04. One signal

path relates to a first functional unit 06 for testing at least the color image of the

identifying characteristic for a color deviation from the reference image. A second

signal path relates to a second functional unit 07 for testing the identifying

characteristic for its affiliation with a defined class of identifying characteristics. A

third signal path relates to a third functional unit 08 for testing the identifying

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characteristic for a defined geometric contour or for an arrangement relative to at least one further identifying characteristic of the material 19. Each test includes a comparison, performed at a comparison location 11, 12, 13, of the first signal 09, which has been made available by the image sensor 02 of the color camera 01 and which has been suitably processed, with a suitably fixed reference variable 16, 17, 18, respectively. The reference variables 16, 17, 18 are stored in a data memory 14, which is part of the evaluating device 03. The respective test results present in the individual signal paths are again reported to the evaluating device 03 for the purpose of being stored there. The functional units, which are relevant to the method for the qualitative evaluation of an imprinted material 19 with at least one identifying characteristic, can also be implemented in a machine which is processing the material 19. This machine can preferably be arranged downstream of, but can also be located upstream of, for example a printing press, preferably a sheet-fed printing press, and in particular a sheet- fed rotary printing press. The material 19, such as a printed sheet 19 having, for example, several identifying characteristics, is imprinted in a printing press at a speed of, for

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example, 18,000 sheets per hour and/or is subsequently further processed in the machine processing these printed sheets 19 at this speed. In the situation where the material 19 being evaluated is embodied as a web 19 of material, the printing speed or the further processing speed of the web 19 can be 15 m/s, for example. Although the testing processes for evaluating the quality of the material 19 to be processed by the printing press or by the machine are calculation-intensive, and the movement speed of the material 19 is high, a dependable evaluation is achieved by the use of the method in accordance with the present invention.

Since the functional units, which are relevant to the method for the qualitative evaluation of an imprinted material 19 with at least one identifying characteristic, are arranged in or at the printing press or the machine processing the material 19, the location for making the reference signal available and the location of the test are identical. The color image and its reference image can be recorded by the same functional units, and in particular can be recorded by the same color camera 01, in the same location, and can be evaluated in the same evaluating device 03.

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[074] The following method steps are performed for the qualitative evaluation of the imprinted material 19 and will now be explained by way of example by referring to Figs. 2 to 11.

[075] A color image of a material 19, which has been imprinted in color and which is arranged in an observation area 21, as seen in Fig. 2, is recorded bythe color camera 01. The color camera 01 has an image sensor 02, which is preferably embodied as a CCD chip 02, and which converts the image information recorded in the observation area 21 into electronic image data, which electronic image data form a first electrical signal 09 that is made available by the color camera 01, or by its image sensor 02. In the course of this conversion, a signal vector 22 is generated by each one of the light-sensitive pixels of the CCD chip 02. The color camera 01 makes available a number of signal vectors 22 corresponding to the number of pixels of the CCD chip, and identified by counting index, to the evaluating device 03 for further processing.

[076] Preferably, each signal vector 22 has three coefficients R, G and B. The coefficients R, G and B correspond to the color values of the three signal

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channels red, green and blue. The vectorially first electrical signal 09 emitted by a pixel is correlated with the recorded color of the imprinted material 19 at the corresponding position in the observation area 21.

[077] The signal vectors 22, whose counting indices are used for describing the arrangement of the respective pixels on the CCD chip 02, constitute raw data for a first correction module 23 for matching the color balance, the brightness and the contrast. For this purpose, each coefficient R, G, B of the signal vector 22 is multiplied by a signal-dependent correction factor K_1, K_2, K_3. Moreover, to the resulting vector is added a correction vector 24 with the fixed value coefficients a_1, a_2 and a_3. First corrected signal vectors 26 are created by this arithmetic operation, which arithmetic operation improves the color balance, the brightness and the contrast of the image data. This goal is achieved because the signal channel-dependent correction factors K_1, K_2, K_3, as well as the coefficients a_1, a_2 and a_3 of the correction vector 24 have been selected in such a way that, in the course of recording the reference gray values black and white, the signal vectors 22 generated by the color camera 01 are transformed in such a way that the

received corrected signal vectors 26 correspond to those reference variables which result as the vectors from the conversion of the known CIELAB color values.

[078] Thereafter, the first corrected signal vectors 26 are provided to a second correction module 27. In the second correction module 27, each first corrected signal vector 26 is multiplied by a quadratic i x i correction matrix 28, wherein i corresponds to the number of coefficients of the corrected signal vector 26, wherein in this case i = 3. The second corrected signal vectors 29 result from this multiplication. The coefficients K_4 to K_{12} of the quadratic correction matrix 28 had previously been determined in a suitable iteration process in such a way that the image information contained in the first corrected signal vectors 26 is brought closer to the color perception of the human eye.

[079] Subsequently, the second corrected signal vectors 29 are forwarded to a third correction module 31. In the third correction module 31, signal channel-dependent correction factors relating to each pixel have been stored in a data memory 14 which, for accommodating the intensity values which depend from the

position of the respective pixels, are multiplied with the coefficients R, G and B.

As a result, the second corrected signal vectors 29 of the first pixel are multiplied

by the correction factors K_{13}, K_{14} and K_{15} in order to calculate a third corrected

signal vector 32 for the first pixel. Preferably, this correction of the second

corrected signal vectors 29 is performed for all of the pixels of the image sensor

02.

[080] The third corrected signal vectors 32 are then passed on to a fourth

correction module 33. In the fourth correction module 33, the coefficients R, G. B

of the third corrected signal vectors 32 are raised to a higher power by a factor γ

and the fourth corrected signal vectors 34 are calculated from this. By raising the

third corrected signal vectors 32 by the factor γ, the non-linear brightness transfer

function of a color monitor 04 is taken into consideration, to which the fourth

corrected signal vectors 34 are transmitted for display.

[081] As previously mentioned, the recording of the image signal by an image

sensor 02 takes place in signal channels R, G, B which are separated from each

other. In the present preferred embodiment, the three signal channels R, G, B

are the three signal channels red R, green G and blue B. Each one of the signal channels R, G, B has an adjustable spectral sensitivity. This has the advantage that the spectral sensitivity of each signal channel R, G, B can be adapted to the spectral sensitivity of the respective cone of the retina of the human eye.

[082] In the course of utilizing the method for checking the color image for a color deviation from a reference image, the spectral contents of an image is analyzed pixel by pixel. To model the two receptive fields red/green and blue/yellow of the human eye, in accordance with Fig. 3 in this method the image sensor signals of the signal channels R, G, B are linked with each other. Prior to the actual linkage by the use of the calculation prescriptions 36, 37, each image sensor signal is subjected to a non-linear transformation 41 in the compensation color channels 38, 39. Because of this, the digital character of the electronically created recordings is taken into consideration. Each signal is subsequently weighted with a coefficient K_i 42 (i = 1...4). It is achieved by this process that a mere intensity change of the initial image does not make a contribution to one of the output signals 43, 44 of the compensation color channels 38, 39. The

generation of the output signals 43, 44 of the compensation color channels 38, 39

takes place analogously to the generation of the signals of the receptive fields in

the human retina. This means that a linkage of the signal channels R, B, G, by

use of the calculation prescriptions 36, 37, is performed in a manner

corresponding to the linkage of the cones of the human retina. For forming the

output signal 43 of the red/green compensation color channel 38, the image

sensor signals of the red signal channel R and the green signal channel G are

linked together by the use of the first calculation prescription 36. For generating

the output signal 44 of the blue/yellow compensation color channel 39, in the

present preferred embodiment, the image sensor signal of the blue signal channel

B is linked with the minimum 46 of the image sensor signals of the red signal

channel R and the green signal channel G by use of the calculation prescription

37. The receptive fields of the human retina are distinguished by a low pass

behavior. Accordingly, in the present preferred embodiment, the signals obtained

by linkage are subjected to low pass filtering 47, for example by the use of a

Gauss low pass filter.

[083] Fig. 4 shows the actual testing of the imprinted material 19, which takes

place in two stages, namely in a learning mode 48 and in a subsequent working

mode 49. The aim of the learning mode 48 is the generation, pixel by pixel, of

reference variables for use as reference data values, which reference data values

are compared in the subsequent working mode 49 with the output signals 43, 44

of the compensation color channels 38, 39 of the corresponding pixels. In the

learning mode 48, the image contents of a reference image 52, or of several

reference images 52, are analyzed in that the image contents of each pixel are

introduced into three signal channels R, G, B, and a subsequent matching, in

accordance with the perception of the image signals of each signal channel R, G,

B, is performed. Thereafter further processing of the image sensor signals is

performed, in accordance with the previously described compensation color

method. The output signals 43, 44 of the compensation color channels 38, 39,

which are obtained for each pixel, are then stored in a data memory 14. In order

to also take permissible fluctuations of the reference images 52 into

consideration, it is useful if several reference images 52 are considered in the

learning mode 48. It is possible, because of this, for the stored reference variables of each pixel to have a permissible fluctuation tolerance. The fluctuation tolerance can be fixed either by minimum/maximum values or by the standard deviation from the received data of the image contents of the reference images 52 of each pixel.

[084] Then, in the working mode 49, a pixel by pixel comparison of the output values 43, 44 of the compensation color channels 38, 39 of an inspection image 53, with the reference variables from the data memory 14, takes place. This comparison can be performed by the use of a linear or of a non- linear classification device 54, and in particular by the use of threshold value classification devices, Euclidic distance classification devices, Bayes classification devices, fuzzy classification devices, or artificial neuronal networks. A good/bad decision subsequently takes place.

[085] Fig. 5 shows a flow diagram of the signal evaluation, in the method for checking the identifying characteristic for its association with a defined class of identifying characteristics, in accordance with the present invention.

[086] First, a grid of M x N windows 56 is placed over the entire color image to be checked, wherein M, N > 1. Each window 56 advantageously consists of m x n pixels, with m, n > 1. A square window 56 of N x N windows 56 is preferably selected, wherein each window 56 consists of n x n pixels. In the testing process, the signal of each window 56 is checked separately.

[087] The two-dimensional color image of the local range is transformed, by use of one or of several two-dimensional spectral transformations 58, into a two-dimensional image in the frequency range. The obtained spectrum is called a frequency spectrum. Since, in the present preferred embodiment, this is a discrete spectrum, the frequency spectrum is also discrete. The frequency spectrum is constituted by the spectral coefficients 59, which arealso called spectral values 59.

[088] The sum formation 61 of the spectral values 59 takes place in the next method step. The sum of the spectral values 59 is called a spectral amplitude value 62. In the present preferred embodiment, the spectral amplitude values 62 constitute the characteristics values 62, i.e. they are identical to the

characteristics values 62.

[089] The characteristics selection 63 follows as a further method step. It is the goal of the characteristics selection 63 to select those characteristics 64 which are characteristic of the image content of the color image to be checked. Characteristic spectral amplitude values 62, which define the characteristic 64 by their position in the frequency range and by their amplitude, as well as linguistic variables, such as "gray", "black" or "white", for example, are possible as characteristics 64.

[090] In the following method step, the fuzzyfication 66, the association of each spectral amplitude value 62 to a characteristic 64 is determined by a soft or by fuzzy association function 67. In other words, weighting is performed.

[091] If, in a learning mode, the association functions 67 are to be matched to reference variables, which are stored in the form of reference data sets, it is useful for the association function 67 to be configured as parametrized monomodal, or as one-dimensional potential functions, in which the parameters of the positive and negative slopes can be separately matched to the reference

variables to be tested. In the working mode, following the learning mode, the

data sets of the image contents, from which the characteristics values 62 of the

color images to be checked result, are weighted with the respective association

functions 67, whose parameters had been determined in the previous learning

mode. This means that for each characteristic 64 a sort of SHOULD BE - IS

comparison takes place between a reference data set, expressed in the

parameters of the association functions 67, and the data set of the color image to

be checked. A soft or a fuzzy association is produced between the respective

characteristics value 62 and the characteristic 64 by the association functions 67.

[092] In the next method step, the interference 68, a substantial conjunctive

linkage 69, also called an aggregation 69, of all of the association functions 67 of

the characteristics 64 takes place, by the use of which, a higher order association

function 71 is created.

[093] The next method step, defuzzyfication 72, determines a concrete

association value 73, or a sympathetic value 73, from the higher order association

function 71. In the course of the classification 74, this sympathetic value 73 is

compared with a previously set threshold value 76, so that a classification

statement can be made. The threshold value 76 is set either manually or

automatically. Setting of the threshold value 76 also takes place in the learning

mode.

[094] The method for checking the identifying characteristic, for a defined

geometric contour and/or for a relative association with at least one further

identifying characteristic of the material, substantially takes place during the

following steps.

[095] In accordance with Fig. 6, a differential image 77 had been formed, in the

course of printing sheets, which are, for example, imprinted with bills 19, wherein

only a portion of the differential image 77, in the area of a bill 19, is represented in

Fig. 8. It can be seen, as depicted in Fig. 6, that the normal print image of the bill

19 has been blanked out of the differential image 77. Only those areas of the print

image, which significantly differ from the background reference value, are

represented as dark fields in the differential image 77. In a strip-shaped expected

range 78, which is indicated by dashed lines, the position of, for example, an

identifying characteristic 79 placed into the printed sheet can vary, which

identifying characteristic can be, in particular, an incorporated window thread 79

which, in accordance with its perforations, is shown in five dark fields 79.

[096] Besides the five dark fields 79 which can be seen in the representation of

the window thread 79, further perforation characteristics are formed in the

differential image 77 as irrelevant dark fields 81 which had been created by print

errors 81, for example.

[097] Fig. 7 shows the differential image 77 following a suitable binary formation,

by the use of which, the irrelevant dark fields 81 were filtered out. As a result,

only the dark fields 79 stemming from the window thread 79 stand out

significantly in the differential image 77.

[098] Fig. 8 represents a mask reference 82 in its geometric shape. The data for

the width 83 and the length 84 of the window thread perforations 79 have been

stored in the mask reference 82. Furthermore, values of the distance 86 between

the window thread perforations 79, and the number of window thread perforations

79 per bill 19, are stored in the mask reference 82.

[099] As is schematically indicated in Fig. 9, during the evaluation the mask

reference 82 is shifted, by the use of technical data operations, in relation to the

differential image 77, until a maximum overlap between the mask reference 82

and the dark fields 79 in the differential image 77 results. Once this maximum

overlap has been achieved, it is possible to draw conclusions regarding the actual

position of the window thread 79 in the print image from the distances 87, 88

which, for example, result from the actual positions in the X and Y directions of

the mask reference 82, in relation to the edges of the bill 19, so that during a

subsequent check of the print image, the areas of the window thread perforations

79 can be blanked out.

[100]   Fig. 10 shows a second mask reference 89, which represents dark fields

91 corresponding to eight window thread perforations 91 in the course of the

check of a bill 19 on a concavely curved support surface.

[101] Fig. 11 schematically represents a differential image 92, in which the

window thread perforations 91 are shown in dark fields 93, such as, for example,

in window threads 93. In this case, the dark field 94 was caused by a print error

94 and not by a window thread perforation 91. Furthermore, a window thread

perforation 91 in the center is not pictured because of the insufficient color

difference between the background and the window thread 93.

[102] To simplify the comparison between the mask reference 89 and the

differential image 92 for position finding, the mask reference 89 is projected onto

a projection line 96, and the light-dark distribution resulting from this projection is

compared with the light-dark distribution resulting from the projection of the

reference image 92 onto a projection line 97. By the use of this one-dimensional

comparison of the light-dark distribution it is possible to determine the position of

the window thread 93 in one direction.

[103] While preferred embodiments of methods for the qualitative evaluation of a

material with at least one identifying characteristic, in accordance with the present

invention, have been set forth fully and completely hereinabove, it will be

apparent to one of skill in the art that various changes in, for example, the types

of press used to print the material to be evaluated, the specific computer used,

and the like could be made without departing from the true spirit and scope of the

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present invention which is accordingly to be limited only by the appended claims.

WHAT IS CLAIMED IS: